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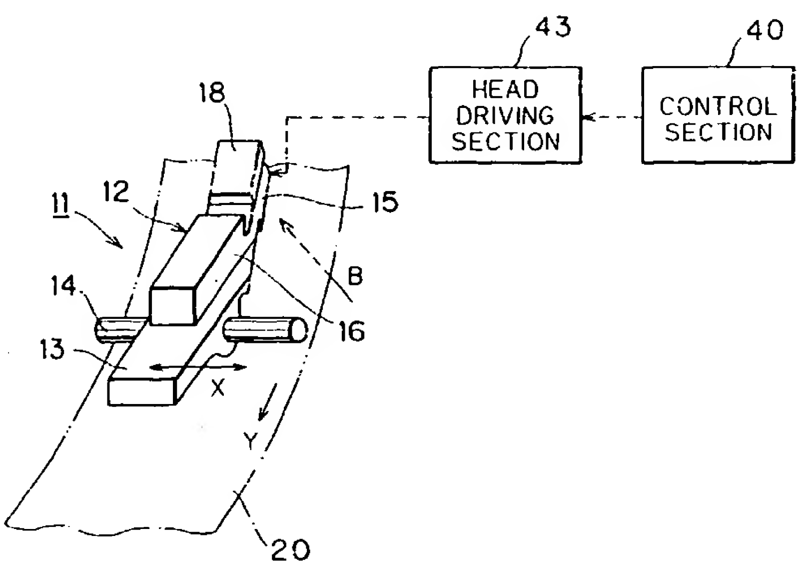
(54) Hot melt ink jet printer ejecting ink droplet of optimum quantity

(57) When a recording density is set to more than 600 by 600 dpi in a hot melt printer, a recording image with excellent quality is obtained when a recording condition is determined to a specific range. For example, a quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 7.2×10^6 to 2.1×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area. This range varies when a pair of pressure rollers are provided for applying a pressure to the recording paper on which the dots are printed. This range also varies when a plate-shaped heating element is provided for heating the printed surface of the recording paper.

FIG. 2(a)



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Description

The present invention relates to a hot melt ink jet printer using droplets of hot melt ink to record information, such as images and characters, on a printing medium, such as paper and transparent recording material.

Because water-based inks and oil-based inks are liquid at room temperature, they easily run and blur when printed on normal paper. Therefore, images printed by ink jet printers using water-based or oil-based inks can have insufficient density. Although a certain level of image density has been achieved using a special type of paper for improving the quality of images, images printed using water-based and oil-based inks are also slow to dry, so the speed at which ink jet printers can print using these inks is limited. Further, operations for replenishing these type of inks are troublesome.

Hot melt ink jet printers, referred to as HMI jet printers hereinafter, have been developed to overcome the problems associated with printing using inks that are liquids at room temperature and to improve image quality and recording speed of ink jet printers. HMI jet printers use an ink that is a solid at room temperature. The ink is melted before it is ejected. The clinging properties of hot melt ink are completely different from water-based and ink-based inks.

HMI jet printers are capable of printing at a recording density of 300 dpi by 300 dpi. However, it is desirable to improve visibility, or image quality, of color images for catalogs and pamphlets. One important condition to be met for improving image quality is to increase recording density. However, merely increasing recording density will not guarantee an improvement in image quality because whether image quality is good or not is determined based on a balance of various judgment standards, such as gradation continuity, and level of optical density. This balance varies greatly depending on the properties of the hot melt ink and on the amount of ink that clings to the recording medium. To increase the printing speed, it is also necessary to improve fixability of inks on the recording paper to prevent unwanted mixing of colors inks.

In order to develop an HMI jet printer capable of good image quality under heretofore unknown conditions of 600 dpi by 600 dpi recording density, the present inventors have performed experiments to find conditions for keeping the overall balance of those conditions, such as gradation continuity, which serve as a basis for determining image quality, within a tolerance range.

Accordingly, it is an object of the present invention to provide an HMI jet printer that is capable of printing high quality images on a recording medium.

It is another object of the present invention to provide an HMI jet printer that can use a plain paper as the recording medium.

To achieve the above and other objects, there is provided, according to one aspect of the present invention, a hot melt ink jet printer which includes an ink jet head for ejecting an ink droplet onto a recording paper: and a paper feed unit for feeding the recording paper. Dots with a recording density more than 600 dpi by 600 dpi are printed on the recording paper by a combination of the ink jet head and the paper feed unit. A quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 7.2×10^6 to 2.1×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area.

Preferably, the ink clinging amount on the unit area of the recording paper is in a range from 1.0×10^7 to 1.7×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

According to another aspect of the present invention, there is provided a hot melt ink jet printer including an ink jet head for ejecting an ink droplet onto a recording paper: a paper feed unit for feeding the recording paper: and pressurizing means for applying a pressure to recording paper on which the dots are recorded by the ink jet head. Dots with a recording density more than 600 dpi by 600 dpi are printed on the recording paper by a combination of the ink jet head and the paper feed unit. A quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 5.4×10^6 to 1.7×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area.

The pressuring means applies a pressure in a range of 3 to 7 tons/m^2 to the recording paper on which the dots are recorded.

Preferably,.the ink clinging amount on the unit area of the recording paper is in a range from 9.0×10^6 to 1.6×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

According to still another aspect of the invention, there is provided a hot melt ink jet printer including an ink jet head for ejecting an ink droplet onto a recording paper: a paper feed unit for feeding the recording paper: and heating means for applying a heat to the recording paper on which the dots are recorded by the ink jet head. Dots with a recording density more than 600 dpi by 600 dpi are printed on the recording paper by a combination of the ink jet head and the paper feed unit. A quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 5.4×10^6 to 1.7×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area.

Preferably, the heating means is a plate-shaped member. The plate-shaped member is disposed so that the surface thereof is in facial contact with the recording paper. A heating temperature of the heating means is set to a temperature for melting the hot melt ink.

Preferably, the ink clinging amount on the unit area of the recording paper is in a range from 7.2×10^6 to 1.3×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

In the present invention, the recording densities in a vertical direction and a horizontal direction on the recording paper are set substantially equal to each other. Further, a plain paper is usable as the recording paper.

The particular features and advantages of the invention as well as other objects will become more apparent from the following description taken in connection with the accompanying drawings, in which:

Fig. 1(a) is a vertical cross-sectional view showing an HMI jet printer according to a first embodiment of the present invention;

Fig. 1(b) is a vertical cross-sectional view showing an HMI jet printer according to a second embodiment of the present invention;

Fig. 1(c) is a vertical cross-sectional view showing an HMI jet printer according to a first embodiment of the present invention;

Fig. 2 (a) is a perspective view, partially in block form, showing a print mechanism provided in the ink jet printer according to the first and third embodiments of the present invention;

Fig. 2 (b) is a perspective view, partially in block form, showing a print mechanism provided in the ink jet printer according to the second embodiment of the present invention;

Fig. 3 is a perspective view showing the head portion of an ink jet head according to the first to third embodiments of the present invention;

Fig. 4(a) is a graphical representation showing a relationship between a drop quantity, coverage and a recording density according to the first embodiment of the present invention;

Fig. 4(b) is a graphical representation showing a relationship between a drop quantity, coverage and a recording density according to the second embodiment of the present invention; and

Fig. 4(c) is a graphical representation showing a relationship between a drop quantity, coverage and a recording density according to the third embodiment of the present invention.

An explanation of an HMI jet printer according to a first embodiment of the present invention will be provided while referring to Figs. 1(a), 2(a), 3 and 4(a).

Fig. 1(a) is a cross-sectional view showing the HMI jet printer according to the first embodiment. Fig. 2(a) is a perspective view showing a print mechanism of the HMI jet printer as viewed from a viewpoint indicated in Fig. 1(a) by an arrow A. The HMI jet printer includes a casing formed from a lower cover 1 and an upper cover 2. Sheet-feed mechanisms 3,4 are provided, aligned from front to rear, at the rear side of the upper cover 2. The sheet-feed mechanisms 3,4 are each capable of storing a shack of sheets 20. Sheet-feed rollers 5,6 are disposed below corresponding sheet-feed mechanisms 3,4. The sheet-feed rollers 5,6 are for feeding out sheets 20 stored in the sheet-feed mechanisms 5,6 toward a transport pathway 7. The transport pathway 7 passes, in order, from the sheet-feed mechanisms 3,4 to a first transport roller 8 and a second transport roller 9 and then to a sheet-discharge tray portion 10 and a sheet-discharge port la. The first and second transport rollers 8,9 quantitatively or consecutively transport the sheets 20 in an auxiliary direction indicated by an arrow in Fig. 1(a). Then, the sheets 20 are discharged out of the HMI jet printer from the sheet-discharge port 1a.

A print mechanism 1 is disposed above the transport pathway 7. The print mechanism 1 includes an ink jet head 12; a carriage 13 on which the ink jet head 12 is mounted; a guide member 14 supporting the carriage 13 to be slidably movable in a main scanning direction; and, although not shown in the drawings, a scanning mechanism for reciprocally moving the carriage 13 along the guide member 14 in the scanning direction. It should be noted that the main scanning direction is indicated by an arrow X in Fig. 2(a) and penetrates through the surface of Fig. 1(a). The main scanning direction is perpendicular to an auxiliary scanning direction, which is indicated by an arrow Y in Fig. 2(a) and which is a direction slanting downward to the left as viewed in Fig. 1(a). The ink jet head 12 includes a head portion 15 for ejecting hot melt ink; and a tank portion 16 for storing ink to be supplied to the head portion 15. Although not shown in the drawings, a piezoelectric element for ejecting ink by changing volume of an ink-filled ink chamber is provided in the head portion 15. A heater portion 18 for maintaining the hot melt ink in a melted condition is also provided in the head portion 15. Although not shown in the drawings, another heater portion for performing the same function as the heater portion 18 is also provided in the tank portion 16. The heater portions enable ejecting the hot melt ink in a liquid condition.

The internal space of each of the tank portion 16 and the head portion 15 is partitioned into four chambers R1 through R4. Hot melt inks of four primary colors are introduced into the respective chambers. The inks of four primary colors are made from a mixture of colorants (2% in mixture ratio) of black (B), yellow (Y), magenta (M) and cyan (C) which is a half tone of blue and green, a paraffin wax (85% in mixture ratio), and ethylene-vinylacetate copolymer (13% in mixture ratio). A color recording image is formed by the four primary color inks ejected from the corresponding nozzles 15b formed in the respective chambers of the heat portion 15.

As shown in Fig. 3, a nozzle array 15e consisting of a plurality of nozzles is formed in each of the chambers R1 through R4 and ejects ink droplets therefrom when the corresponding chamber is deformed by the actuation of the piezoelectric element. With respect to the chamber R1, the nozzles 15b are aligned at a constant pitch in the auxiliary scanning direction (Y direction) perpendicular to the main scanning direction (X direction). The nozzles are identified by nozzle numbers P(0) through P(N). The ink jet head 12 is oriented in a direction So that the nozzle surface 15a in which these nozzles are formed faces a recording paper 20. The ink ejected from each nozzle 15b impinges against the recording paper 20 held in a direction perpendicular to the direction in which the ink is ejected. The recording paper 20 is printed with dots by the ink jet head 12 moving in the main scanning direction while feeding the recording paper in the auxiliary scanning direction.

An arrangement of the print mechanism 11 as shown in Fig. 2(a) is provided in the HMI jet printer according to the first embodiment. By this arrangement, a quantity (volume) of an ink droplet ejected from the nozzle can be experimentally changed. The arrangement shown in Fig. 2(a) includes a head driving section 43 for applying a drive signal to the driving element (piezoelectric element, not shown) of the ink jet head 12, and a control section 40 for controlling the drive signal output from the head driving section 43 or changing the driving voltage of the drive signal. In order to eject an ink droplet of a desired quantity, an operator inputs a desired quantity of ink to the control section 40. The control section 40 computes a driving voltage based on the inputted quantity of ink for applying to the head driving section 43. The HMI jet printer with such an arrangement is capable of setting a quantity of ink droplet in a range from 10 to 70 pl.

The driving voltage output from the control section 40 is determined based on experimental results. The experiment is performed in such a manner that weight of several ink droplets (preferably, 100 droplets or so) ejected from the nozzle in response to a selected driving voltage is measured and then a quantity per one ink droplet is computed by referring to the specific weight of the used ink. Such an experiment is repeatedly conducted several times while changing the parameter of the driving voltage. Based on the experimental results. a relationship between the ink quantity and the driving voltage is obtained. The control section 40 stores a reference table indicative of the relationship therebetween. Using the data contained in the reference table, the control section 40 is capable of converting an ink quantity input to the control section 40 to a corresponding driving voltage. Alternatively, with the provision of a sensor capable of sensing an amount of ink decreased in the tank portion 16, the relationship between the ink quantity and the driving voltage can be obtained from the decreased amount of ink after ejecting several ink droplets with a set driving voltage.

The HMI jet printer of the first embodiment has the following arrangement capable of experimentally changing the vertical and horizontal recording densities on the recording paper. The horizontal recording density, that is, the recording density in the main scanning direction (X direction), is determined by the timing at which the drive signal is supplied to the driving element during the movement of the carriage 13. This timing control is effected by the control section 40. The vertical recording density, that is, the recording density in the auxiliary scanning direction (Y direction) can be changed through the use of a head having a nozzle-to-nozzle pitch corresponding to the recording density. If the head formed with high density nozzles is not available, a head formed with nozzles of a staggered arrangement can provide a desired recording density. A plurality of heads having different vertical recording densities are prepared and used in succession by mounting on the carriage 13. By the selective use of the heads, the vertical recording density can be changed. For each of the heads, a quantity of one ink droplet must be measured in advance through the experiments described above.

Using the HMI jet printer arranged as described above, the recording density is set to 600 dpi by 600 dpi. In this condition. the quality of the image printed on a plain paper is evaluated while changing the ink droplet quantity of hot melt ink (hereinafter referred to as "drop quantity"). The plain paper is used because it is generally used and economical. The hot melt ink used in the experiments contains a paraffin wax (paraffin wax standard 155), ethylene-vinylacetate copolymer (Evaphilex 210 manufactured by Mitui Polychemical Company), C.I. (color index) solvent black 29 (CIBA-GEIGY (Japan) Limited) as black colorant. C.I. solvent yellow 162 (BASF Company) as yellow colorant. C.I. solvent 49 (BASF Company) as magenta colorant, and C.I. solvent blue 70 (BASF Company) as cyan colorant. The mixture ratio of each color is 85 % of paraffin wax, 13 % of ethylene-vinylacetate copolymer, and 2 % of colorant. The recording paper used in the experiments is Xerox 4024 (20 pounds, plain paper). The pressing condition is set to 5 tons/m^2.

Evaluation of the print quality is decided by majority of 30 panelists. Whether or not the recording image is within a tolerance range is determined by a ratio of the number of panelists (hereinafter referred to as "supporting rate") who judge that the image is good in visual impression. The supporting rate will be given by percent. The factors to determine that the image is good in visual impression are clearness or distinct of a color block (this will be referred to as "image (1)" hereinafter), distinct of a presentation (this will be referred to as "image (2)" hereinafter), and distinct of photo print (this will be referred to as "image (3)" hereinafter). The total evaluation of these factors determines whether or not the image quality if within the tolerance range. The results of evaluation are shown in Table 1(a) attached to the end of the description.

As is apparent from Table 1(a), it is confirmed that when the drop quantity is in a range from 20 to 50 pl, high quality images. that is, images recognized by majority of people as having high clearness or distinct and a good visual im-

pression are obtained.

Table 1(a) shows qualitative experimental results. In order to evaluate the image quality from the quantitative point of view, a relationship between the drop quantity, density and gradation of the image is investigated. Under a condition in which the dots are printed with a predetermined recording density while ejecting a predetermined quantity of ink for each droplet, the experiments were performed to measure the change in density (0 % to 100 %) of each primary color when a ratio of dots printed on an M-by-N matrix picture element (this ratio will be referred to as "coverage" and represented by percentage hereinafter) is changed. When the coverage is 100 %, printing is effected to all over the recording area. When the density is 100 %, the background white color of the recording paper is not visible at all within the M-by-N matrix area. The results of experiments are indicated in the graph shown in Fig. 4(a). Fig. 4(a) indicates a relationship between the coverage and the density when the drop quantity is changed in a range from 10 to 70 pl in which the recording density is set to 600 by 600 dpi. In Fig. 4(a), the axis of abscissas represents the coverage (%), and the axis of ordinates, density (%).

As can be appreciated from Fig. 4(a), when the drop quantity is less than 20 pl, the image can be recorded with a density less than 80 % even if the coverage is 100 %. Therefore, the image obtained is low in optical density and gives an impression that the color is light and the contrast of the image is less perceivable. Consequently, the image does not give a good visual perception. On the other hand, when the drop quantity exceeds 55 pl, the density of the image becomes 100 % when the coverage is increased up to 80%. That is, the density gradually changes when the coverage is in the range from 0 to 80 %, however, the density is 100 % when the coverage is above 80 %. This means that the density of the image printed with the drop quantity exceeding 55 pl is too high. The density change is not uniform for the overall range of coverage. It can be appreciated that the gradation perceived in the entire range of the coverage is not continuous. When the drop quantity is in a range between 30 to 45 pl, when one of the coverage and the density has reached 100 %, the remainder is more than approximately 90 %. It can therefore be appreciated that in this range, the image quality is a high level in terms of recording density (optical density) and gradation. To summarize, the drop quantity that gives high recording quality is in a range from 20 to 55 pl, preferably from 30 to 45 pl, when printing with 600 by 600 dpi density. This conclusion meets the experimental results shown in Table 1(a).

The measurement results as explained above is obtained when the recording density is set to 600 by 600 pi. For the HMI jet printers printing the images with a recording density different from 600 by 600 dpi, the optimum drop quantity is set to a different value. Table 2(a) shows the results of experiments for 720 by 720 dpi and 900 by 900 dpi recording densities performed in the same manner as described above. The reason for setting the vertical and horizontal recording densities to the same value in the above instances is that almost all the popular ink jet printers have a main mode having the same recording density in the vertical and horizontal directions and that there is a high demand from the users to adopt this mode.

As is apparent from Table 2(a), optimum drop quantity differs depending on the recording density. However, there is a common tendency in the drop quantity in relation to the recording density if the drop quantity is converted to an ink clinging amount per one square inches when its overall area is recorded with ink. Specifically, the ink clinging amount in a range from 7.2×10^6 through 2.1×10^7 pl/inch^2 provides an allowable range of recording quality regardless of the recording density. Further, Table 2(a) indicates that the recording quality is excellent when the ink clinging amount is set in a range from 1.0×10^7 through 1.7×10^7 pl/inch^2.

Therefore, when the HMI jet printers with a recording density more than 600 by 600 dpi are designed and manufactured, the drop quantity is set so that the ink clinging amount when the ink is recorded in an overall area is in a range from 7.2×10^6 through 2.1×10^7 pl/inch^2, preferably in a range from 1.0×10^7 through 1.7×10^7 pl/inch^2. The drive signal (for example, the drive voltage) is set so that the thus set drop quantity is attained. Then, by applying the thus set drive signal to the driving element, a recording quality having a high optical density can be obtained while preserving a continuously changing gradation.

Based on the above-described experiments and observations, description will be made with respect to designing and manufacturing HMI jet printers capable of recording images with 800 by 800 dpi. A drop quantity per one dot is computed based on the ink clinging amount ranging from 1.0×10^7 through 1.7×10^7 pl/inch^2.

$$1.0 \times 10^7/800^2 = 15.6 \text{ pl}$$

$$1.7 \times 10^7/800^2 = 26.6 \text{ pl}$$

Therefore, it can be appreciated that the optimum range of the drop quantity is from 15.6 to 26.6 pl. A value falling within this range, for example, 20 dl, is selected as the drop quantity per one droplet, and the drive voltage is set so that the drop quantity thus selected can be ejected from the nozzle.

Using the printer having an arrangement as shown in Figs. 1(a), 2(a) and 3, the arrangement of the control section

shown in Fig. 2(a) is set to determine the ejection timing so that the recording density becomes 800 by 800 dpi. Also, the control section 40 controls the head driving section 43 so that the latter section outputs the driving signal set as described above to the driving element

While the first embodiment describes the HMI jet printer having a mode capable of printing with 600 by 600 dpi recording density, the first embodiment can also be applied to the HMI jet printers having dual modes capable of selectively printing with more than 600 by 600 dpi recording density and with less than 600 by 600 dpi recording density.

Next, a second embodiment of the present invention will be described while referring to Figs. 1(b), 2(b), 3 and 4. The HMI jet printer according to the second embodiment is similar to that shown in Figs. 1(a) and 2(a) according to the first embodiment, the difference being in the provision of a pair of pressing rollers 30 serving as pressing means. The pair of pressing rollers 30 is disposed below the ink jet head 12 and at the terminal end of the transport pathway 7 so as to nip the recording paper 20 between the rollers 30. The ink droplet clinging to the recording paper 20 is in a dome shaped configuration before the recording paper 20 passes through the nip between the pressing rollers 30. After passing through the nip therebetween, the dome-shaped ink droplet is rolled to have a thin film circular image and fixed to the recording paper 20. A pressing force is condition is in a range between 3 through 7 tons/m^2, preferably between 4 to 6 tons/m^2. If the pressing force is weaker than the lower limit of the above range, fixing of the ink droplet on the recording paper 20 is insufficient and smear of the image is still likely to occur. On the other hand, if the pressing force is stronger than the upper limit of the above range, feathering is notable and the image becomes dull. The size of the pressure roller, the number of the pairs of the pressure rollers to be used, the material in the surface of the pressure roller, and the position of the pressure roller pairs to be placed can be changed appropriately.

Using the HMI jet printer arranged as described above, the recording density is set to 600 dpi by 600 dpi. In this condition, the quality of the image printed on a plain paper is evaluated while changing the drop quantity. Similar to the first embodiment, the plain paper is used because it is generally used and economical. The composition of the ink used in the second embodiment is exactly the same as that used in the first embodiment. The pressure exerted by the pressure rollers is set to 5 tons/m^2. The evaluation of the print quality is decided in the same manner as in the first embodiment. The results of evaluation are shown in Table 1(b) attached to the end of the description.

As is apparent from Table 1(b), it is confirmed that when the drop quantity is in a range from 20 to 40 pl, high quality images, that is, images recognized by majority of people as having high clearness or distinct and a good visual impression are obtained.

Similar to the first embodiment, evaluation of the image quality from the quantitative point of view is performed. The quantitative evaluation is performed in the same way as in the first embodiment. The results of experiments are indicated in the graph shown in Fig. 4(b).

As can be appreciated from Fig. 4(b), when the drop quantity is less than 15 pl, the image can be recorded with a density less than 80 % even if the coverage is 100 %. Therefore, the image obtained is low in optical density and gives an impression that the color is light and the contrast of the image is less perceivable. Consequently, the image does not give a good visual perception. On the other hand, when the drop quantity exceeds 45 pl, the density of the image becomes 100 % when the coverage is increased up to 80%. That is, the density gradually changes when the coverage is in the range from 0 to 80 %, however, the density is 100 % when the coverage is above 80 %. This means that the density of the image printed with the drop quantity exceeding 45 pl is too high. The density change is not uniform for the overall range of coverage. It can be appreciated that the gradation perceived in the entire range of the coverage is not continuous. When the drop quantity is in a range from 25 to 40 pl, when one of the coverage and the density has reached 100 %, the remainder is more than approximately 90 %. It can therefore be appreciated that in this range, the image quality is a high level in terms of recording density (optical density) and gradation, To summarize, the drop quantity that gives high recording quality is in a range from 15 to 45 pl, preferably from 25 zto 40 pl, when printing with 600 by 600 dpi density. This conclusion meets the experimental results shown in Table 2(a).

The measurement results as explained above is obtained when the recording density is set to 600 by 600 pi. For the HMI jet printers printing the images with a recording density different from 600 by 600 dpi, the optimum drop quantity is set to a different value. Table 2(b) shows the results of experiments for 720 by 720 dpi and 900 by 900 dpi recording densities performed in the same manner as described above.

As is apparent from Table 2(b), optimum drop quantity differs depending on the recording density. However, there is a common tendency in the drop quantity in relation to the recording density if the drop quantity is converted to an ink clinging amount per one square inches when its overall area is recorded with ink. Specifically, the ink clinging amount in a range from 5.4×10^6 through 1.7×10^7 pl/inch^2 provides an allowable range of recording quality regardless of the recording density. Further, Table 2(b) indicates that the recording quality is excellent when the ink clinging amount is set in a range from 9.0×10^6 through 1.6×10^7 pl/inch^2.

Therefore, when the HMI jet printers with a recording density more than 600 by 600 dpi are designed and manufactured, the drop quantity is set so that the ink clinging amount when the ink is recorded in an overall area is in a range from 5.4×10^6 through 1.7×10^7 pl/inch^2, preferably in a range from 9.0×10^6 through 1.6×10^7 pl/inch^2. The drive signal (for example, the drive voltage) is set so that the thus set drop quantity is attained. Then, by applying the

thus set drive signal to the driving element, a recording quality having a high optical density can be obtained while preserving a continuously changing gradation.

Based on the above-described experiments and observations, description will be made with respect to designing and manufacturing HMI jet printers capable of recording images with 800 by 800 dpi. A drop quantity per one dot is computed based on the ink clinging amount ranging from 9.0×10^6 through 1.6×10^7 pl/inch^2.

$$9.0 \times 10^6/800^2 = 14.1 \text{ pl}$$

$$1.6 \times 10^7/800^2 = 25.0 \text{ pl}$$

Therefore, it can be appreciated that the optimum range of the drop quantity is from 14.1 to 25.0 pl. A value falling within this range, for example, 20 dl, is selected as the drop quantity per one droplet, and the drive voltage is set so that the drop quantity thus selected can be ejected from the nozzle.

Using the printer having an arrangement as shown in Figs. 1(a), 2(a) and 3, the arrangement of the control section shown in Fig. 2(b) is set to determine the ejection timing so that the recording density becomes 800 by 800 dpi. Also, the control section 40 controls the head driving section 43 so that the latter section outputs the driving signal set as described above to the driving element.

Next, a third embodiment of the present invention will be described while referring to Figs. 1(c), 2(a), 3 and 4(c). The HMI jet printer according to the third embodiment is similar to that shown in Figs. 1(a) and 2(a) according to the first embodiment, the difference being in the provision of a plate-shaped heating platen 40. The heating platen 40 is disposed immediately below the ink jet head 12 so as to confront the nozzle surface 15e. The heating platen 40 is disposed along the transport pathway 7 so as to be in facial contact with the surface of the recording paper 20. The heating temperature of the heating platen 40 is set to 40'C or above 40°C. The hot melt ink is melted when heated up to this temperature. The top portion of a dome-shaped ink droplet is melted, runs into the paper and therefore is flattened due to heat applied thereto. The shape of the heating platen can be determined as desired insofar as it's surface is almost the same size as the nozzle surface 15a and is capable of supporting the recording paper. The heating platen may be disposed so that it indirectly contacts the surface of the recording paper 20

Using the HMI jet printer arranged as described above, the recording density is set to 600 dpi by 600 dpi. In this condition, the quality of the image printed on a plain paper is evaluated while changing the drop quantity. Similar to the first and second embodiments, the plain paper is used because it is generally used and economical. The composition of the ink used in the third embodiment is exactly the same as that used in the first embodiment. The evaluation of the print quality is decided in the same manner as in the first and second embodiments. The results of evaluation are shown in Table 1(c) attached to the end of the description.

As is apparent from Table 1(c), it is confirmed that when the drop quantity is in a range from 20 to 40 pl, high quality images, that is, images recognized by majority of people as having high clearness or distinct and a good visual impression are obtained.

Similar to the first and second embodiments, evaluation of the image quality from the quantitative point of view is performed. The quantitative evaluation is performed in the same way as in the first and second embodiment. The results of experiments are indicated in the graph shown in Fig. 4(c).

As can be appreciated from Fig. 4(c), when the drop quantity is less than 15 pl, the image can be recorded with a density less than 80 % even if the coverage is 100 %. Therefore, the image obtained is low in optical density and gives an impression that the color is light and the contrast of the image is less perceivable. Consequently, the image does not give a good visual perception. On the other hand, when the drop quantity exceeds 45 pl, the density of the image becomes 100 % when the coverage is increased up to 80%. That is, the density gradually changes when the coverage is in the range from 0 to 80 %, however, the density is 100 % when the coverage is above 80 %. This means that the density of the image printed with the drop quantity exceeding 45 pl is too high. The density change is not uniform for the overall range of coverage. It can be appreciated that the gradation perceived in the entire range of the coverage is not continuous. When the drop quantity is in a range from 25 to 35 pl, when one of the coverage and the density has reached 100 %, the remainder is more than approximately 90 %. It can therefore be appreciated that in this range, the image quality is a high level in terms of recording density (optical density) and gradation. To summarize, the drop quantity that gives high recording quality is in a range from 15 to 45 pl, preferably from 20 to 35 pl, when printing with 600 by 600 dpi density. This conclusion meets the experimental results shown in Table 2(a).

The measurement results as explained above is obtained when the recording density is set to 600 by 600 pi. For the HMI jet printers printing the images with a recording density different from 600 by 600 dpi, the optimum drop quantity is set to a different value. Table 2(c) shows the results of experiments for 720 by 720 dpi and 900 by 900 dpi recording densities performed in the same manner as described above.

As is apparent from Table 2(c), optimum drop quantity differs depending on the recording density. However, there is a common tendency in the drop quantity in relation to the recording density if the drop quantity is converted to an ink clinging amount per one square inches when its overall area is recorded with ink. Specifically, the ink clinging amount in a range from 5.4×10^6 through 1.7×10^7 pl/inch^2 provides an allowable range of recording quality regardless of the recording density. Further, Table 2(c) indicates that the recording quality is excellent when the ink clinging amount is set in a range from 7.2×10^6 through 1.3×10^7 pl/inch^2.

Therefore, when the HMI jet printers with a recording density more than 600 by 600 dpi are designed and manufactured, the drop quantity is set so that the ink clinging amount when the ink is recorded in an overall area is in a range from 5.4×10^6 through 1.7×10^7 pl/inch^2, preferably in a range from 7.2×10^6 through 1.3×10^7 pl/inch^2. The drive signal (for example, the drive voltage) is set so that the thus set drop quantity is attained. Then, by applying the thus set drive signal to the driving element, a recording quality having a high optical density can be obtained while preserving a continuously changing gradation.

Based on the above-described experiments and observations, description will be made with respect to designing and manufacturing HMI jet printers capable of recording images with 800 by 800 dpi. A drop quantity per one dot is computed based on the ink clinging amount ranging from 7.2×10^6 through 1.3×10^7 pl/inch^2. Therefore, it can be appreciated that the optimum range of the drop quantity is from 11.3 to 20.3 pl. A value falling within this range, for example, 15 dl, is selected as the drop quantity per one droplet, and the drive voltage is set so that the drop quantity thus selected can be ejected from the nozzle.

Using the printer having an arrangement as shown in Figs. 1(c), 2(a) and 3, the arrangement of the control section shown in Fig. 2(a) is set to determine the ejection timing so that the recording density becomes 800 by 800 dpi. Also, the control section 40 controls the head driving section 43 so that the latter section outputs the driving signal set as described above to the driving element.

Table 1(a)

[RECORDING DENSITY 600×600dpi]

	SUPPORTING RATE (%)		
DROP QUANTITY	IMAGE (1)	IMAGE (2)	IMAGE (3)
10pl	38	52	33
20pl	100	86	100
30pl	100	86	95
40pl	95	71	67
50pl	76	33	29
60pl	24	10	5
70pl	19	5	0

Table 1(b)

RECORDING DENSITY [600×600dpi]

	SUPPORTING RATE		
DROP QUATITY	IMAGE (1)	IMAGE (2)	IMAGE (3)
10pl	52	52	24
20pl	95	86	67
30pl	100	95	95
40pl	95	71	95
50pl	33	24	33
60pl	24	10	5
70pl	19	0	0

Table 1(c)

[RECORDING RATE 600×600dpi]

	SUPPORTING RATE (%)		
DROP QUANTITY	IMAGE (1)	IMAGE (2)	IMAGE (3)
10pl	33	37	24
20pl	71	67	86
30pl	100	86	95
40pl	100	95	100
50pl	86	52	37
60pl	33	19	5
70pl	24	5	0

Table 2(a)

RECORDING DENSITY (dpi)	DROP QUANTITY (pl)	INK CLINGING AMOUNT (pl/inch^2)	EVALUATION
600 × 600	10	3.60×10^6	c1
	15	5.40×10^6	b1
	20	7.20×10^6	a
	25	9.00×10^6	a
	30	1.08×10^7	a
	35	1.26×10^7	a
	40	1.44×10^7	b2
	45	1.62×10^7	b2
	50	1.80×10^7	c2
	55	1.98×10^7	c2
	60	2.16×10^7	c2
720 × 720	10	5.18×10^6	c1
	15	7.78×10^6	a
	20	1.04×10^7	a
	25	1.30×10^7	a
	30	1.56×10^7	b2
	35	1.81×10^7	c2
	40	2.07×10^7	c2
	45	2.33×10^7	c2
900 × 900	10	8.10×10^6	a
	15	1.21×10^7	a
	20	1.62×10^7	b2
	25	2.03×10^7	c2
	30	2.43×10^7	c2

a: High optical density and excellent in gradation

b1: Optical density is slightly lowered than the case of a, but the image quality is within a tolerance range

b2: Gradation is slightly lowered than the case of a, but the image quality is within a tolerance range

c1: Optical density is too low, so the image quality is not satisfactory

c2: Gradation is too bad, so that image quality is not satisfactory

Table 2(b)

RECORDING DENSITY (dpi)	DROP QUANTITY (pl)	INK CLINGING AMOUNT (pl/inch^2)	EVALUATION
600 × 600	10	3.60×10^6	c1
	15	5.40×10^6	b1
	20	7.20×10^6	b1
	25	9.00×10^6	a
	30	1.08×10^7	a
	35	1.26×10^7	a
	40	1.44×10^7	a
	45	1.62×10^7	b2
	50	1.80×10^7	c2
	55	1.98×10^7	c2
	60	2.16×10^7	c2
720 × 720	10	5.18×10^6	c1
	15	7.78×10^6	b1
	20	1.04×10^7	a
	25	1.30×10^7	a
	30	1.56×10^7	a
	35	1.81×10^7	c2
	40	2.07×10^7	c2
	45	2.33×10^7	c2
900 × 900	10	8.10×10^6	b1
	15	1.21×10^7	a
	20	1.62×10^7	b2
	25	2.03×10^7	c2
	30	2.43×10^7	c2

a: High optical density and excellent in gradation

b1: Optical density is slightly lowered than the case of a, but the image quality is within a tolerance range

b2: Gradation is slightly lowered than the case of a, but the image quality is within a tolerance range

c1: Optical density is too low, so the image quality is not satisfactory

c2: Gradation is too bad, so that image quality is not satisfactory

Table 2(c)

RECORDING DENSITY (dpi)	DROP QUANTITY (pl)	INK CLINGING AMOUNT (pl/inchP²)	EVALUATION
600 × 600	10	3.60×10^6	c1
	15	5.40×10^6	c1
	20	7.20×10^6	b1
	25	9.00×10^6	b1
	30	1.08×10^7	a
	35	1.26×10^7	a
	40	1.44×10^7	a
	45	1.62×10^7	a
	50	1.80×10^7	b2
	55	1.98×10^7	b2
	60	2.16×10^7	c2
	70	2.52×10^7	c2
720 × 720	10	5.18×10^6	c1
	15	7.78×10^6	b1
	20	1.04×10^7	a
	25	1.30×10^7	a
	30	1.56×10^7	a
	35	1.81×10^7	b2
	40	2.07×10^7	b2
	45	2.33×10^7	c2
	50	2.59×10^7	c2
900 × 900	10	8.10×10^6	b1
	15	1.21×10^7	a
	20	1.62×10^7	a
	25	2.03×10^7	b2
	30	2.43×10^7	c2
	35	2.84×10^7	c2

a: High optical density and excellent in gradation

b1: Optical density is slightly lowered than the case of a, but the image quality is within a tolerance range

b2: Gradation is slightly lowered than the case of a, but the image quality is within a tolerance range

c1: Optical density is too low, so the image quality is not satisfactory

c2: Gradation is too bad, so that image quality is not satisfactory

Claims

1. A hot melt ink jet printer comprising:

an ink jet head for ejecting an ink droplet onto a recording paper; and
a paper feed unit for feeding the recording paper, dots with a recording density more than 600 dpi by 600 dpi

being printed on the recording paper by a combination of said ink jet head and said paper feed unit, wherein a quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 7.2×10^6 to 2.1×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area.

2. The hot melt printer according to claim 1, wherein the ink clinging amount on the unit area of the recording paper is preferably in a range from 1.0×10^7 to 1.7×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

3. The hot melt printer according to claim 1 wherein a quantity of ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 5.4×10^6 to 1.7×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area.

4. The hot melt printer according to claim 1, wherein the ink clinging amount on the unit area of the recording paper is preferably in a range from 9.0×10^6 to 1.6×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

5. The hot melt printer according to claim 1, wherein the ink clinging amount on the unit area of the recording paper is preferably in a range from 7.2×10^6 to 1.3×10^7 pl/inch^2 when the dots are printed in the overall area of the unit area.

6. The hot melt printer according to any preceding claim, wherein the recording densities in a vertical direction and a horizontal direction on the recording paper are set substantially equal to each other.

7. The hot melt printer according to any preceding claim, wherein a plain paper is used as the recording paper.

8. The hot melt printer according to any preceding claim, further comprising:
pressurizing means for applying a pressure to recording paper on which the dots are recorded by said ink jet head.

9. The hot melt printer according to claim 8, wherein said pressuring means comprises a pair rollers.

10. The hot melt printer according to claim 8 or 9, wherein said pressuring means applies a pressure in a range of 3 to 7 tons/m^2 to the recording paper on which the dots are recorded.

11. A hot melt ink jet printer comprising:
heating means for applying a heat to the recording paper on which the dots are recorded by said ink jet head.

12. The hot melt printer according to claim 11, wherein said heating means comprises a plate-shaped member having a surface, said plate-shaped member being disposed so that the surface thereof is in facial contact with the recording paper.

13. The hot melt printer according to claim 11 or 12, wherein a heating temperature of said heating means is set to a temperature for melting the hot melt ink.

FIG. 1(a)

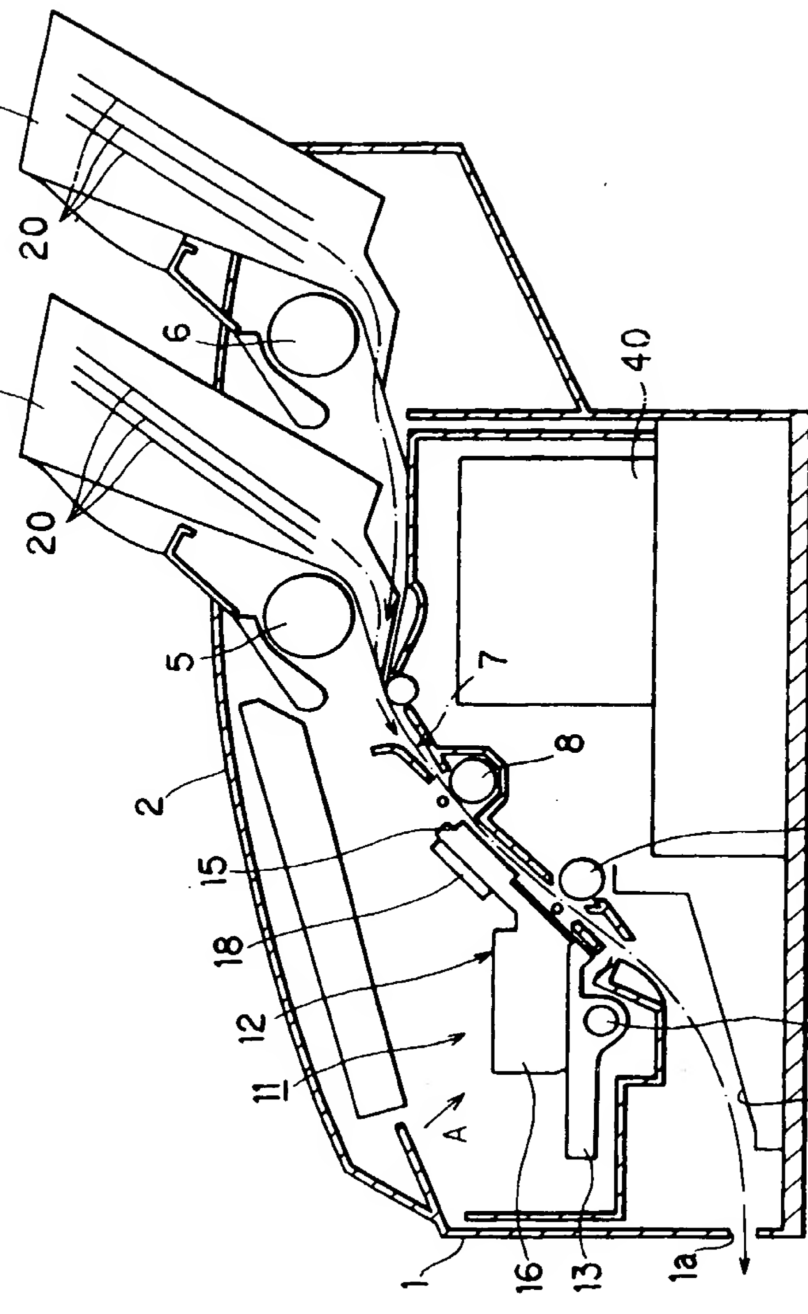


FIG. 1(b)

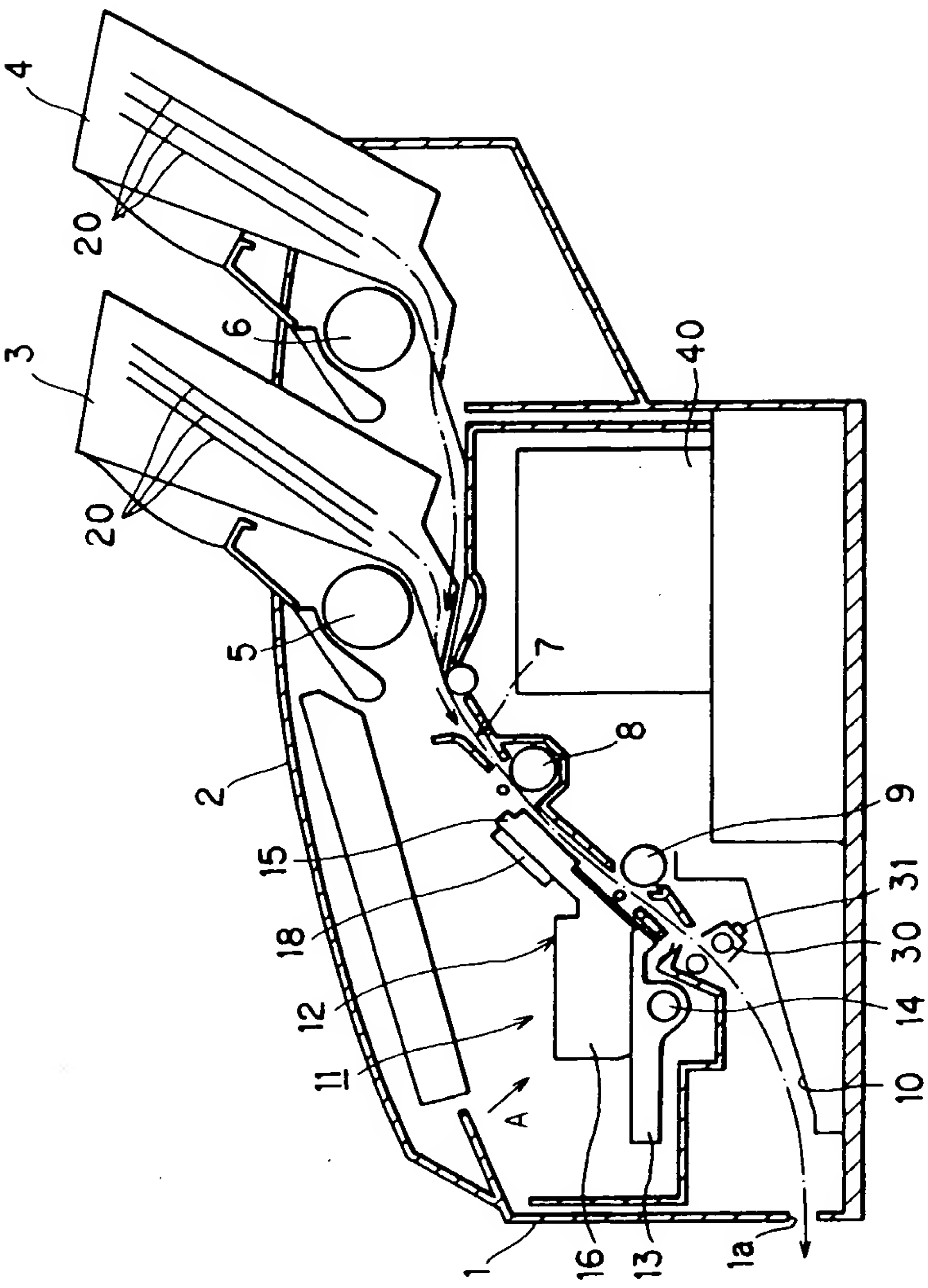


FIG. 1(c)

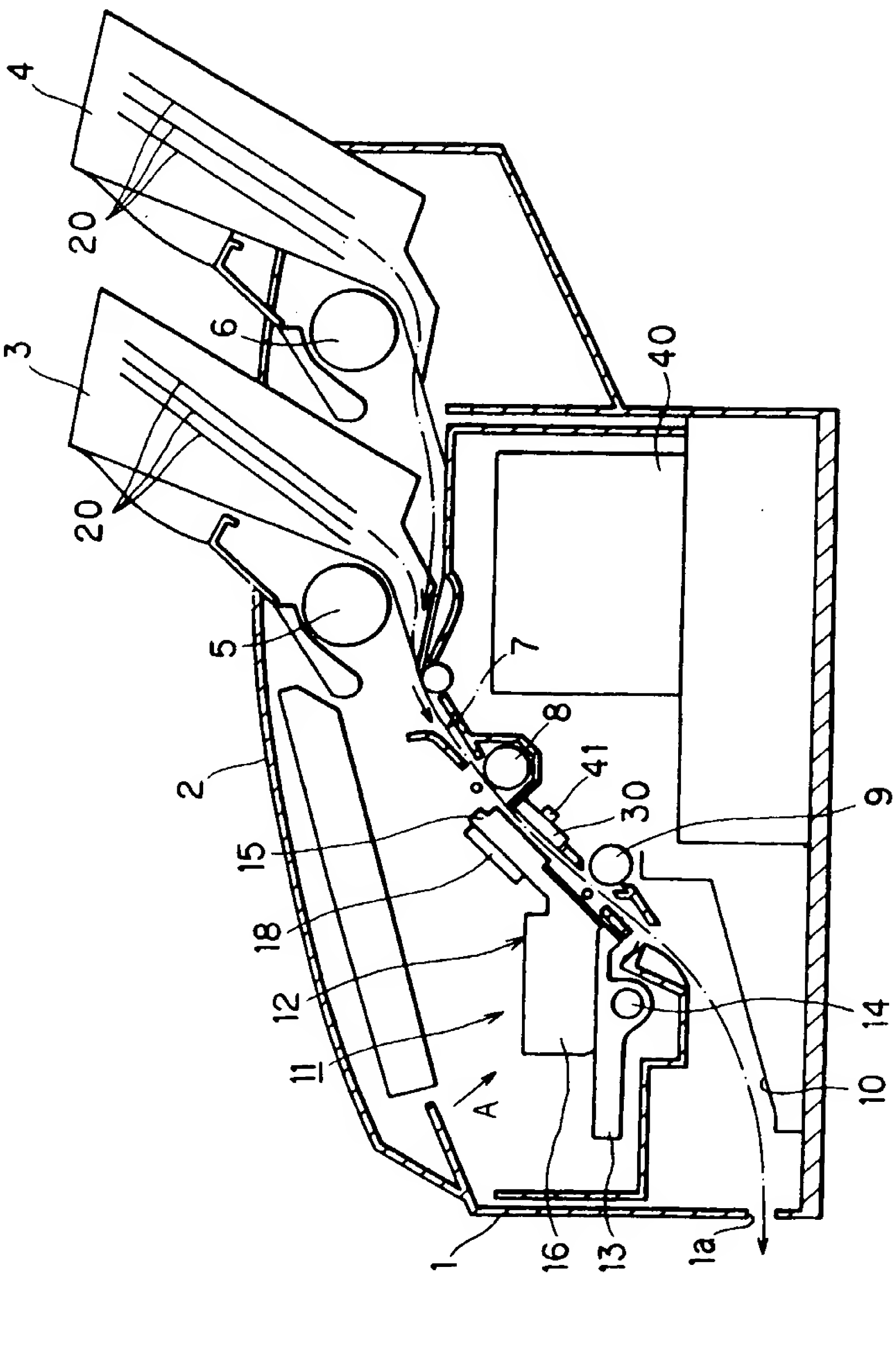


FIG. 2(a)

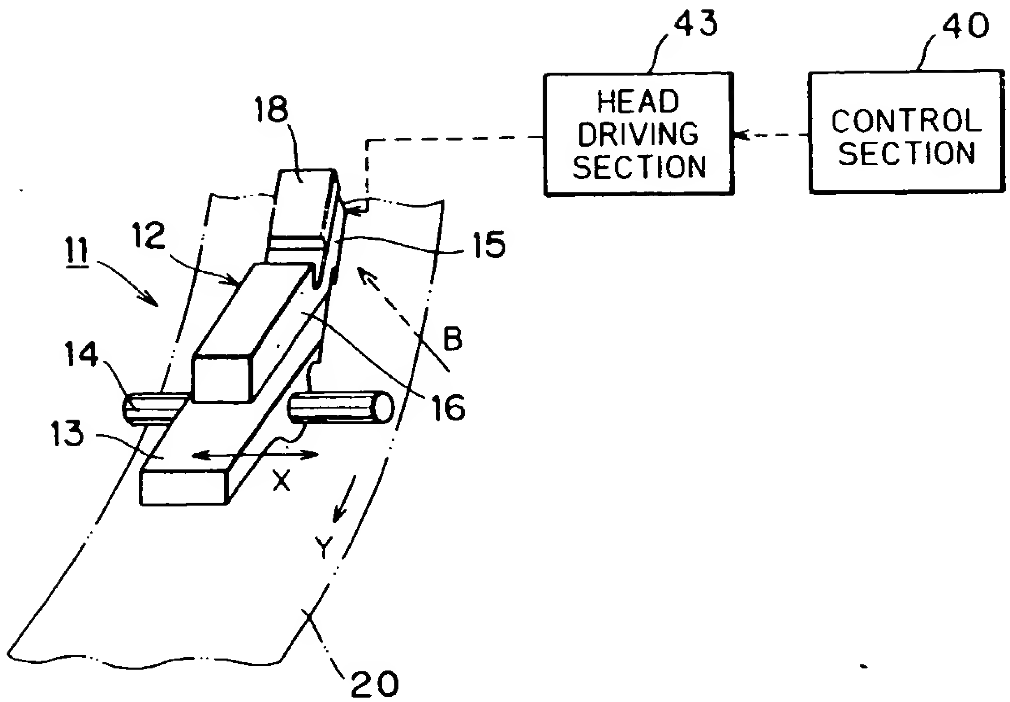

43
40
HEAD DRIVING SECTION
CONTROL SECTION
18
11
12
15
B
14
16
13
X
Y
20

FIG. 2(b)

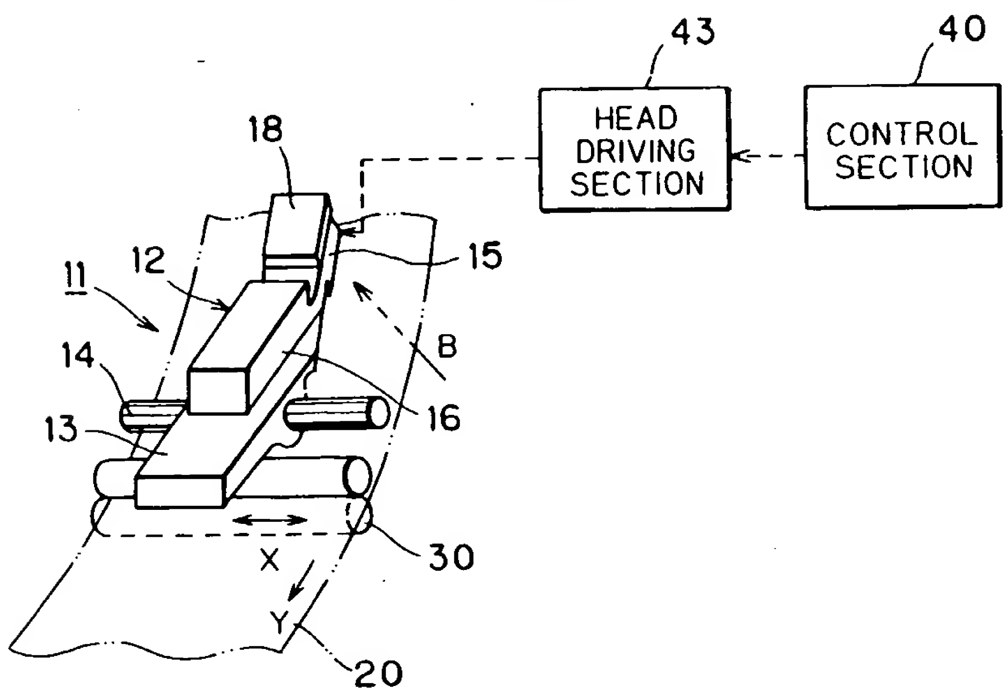

43
40
HEAD DRIVING SECTION
CONTROL SECTION
18
15
11
12
B
14
16
13
30
X
Y
20

FIG. 3

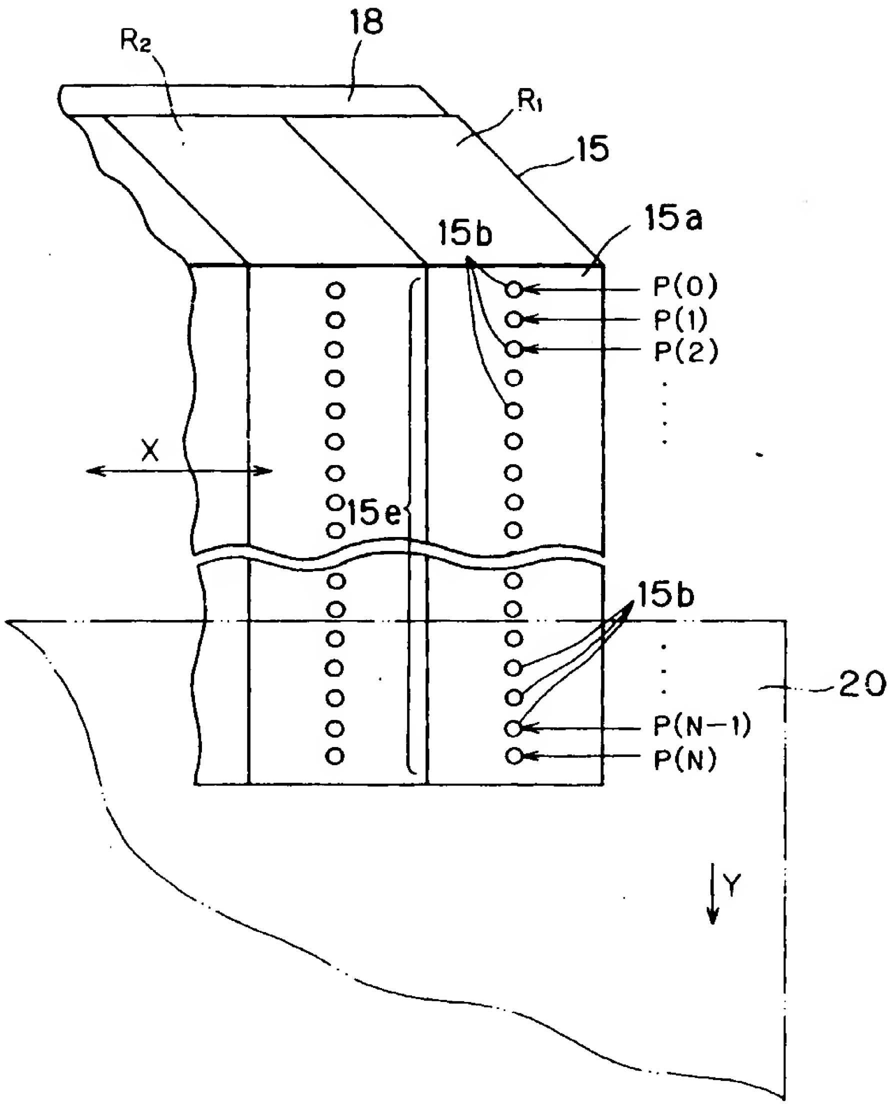


FIG. 4(a)

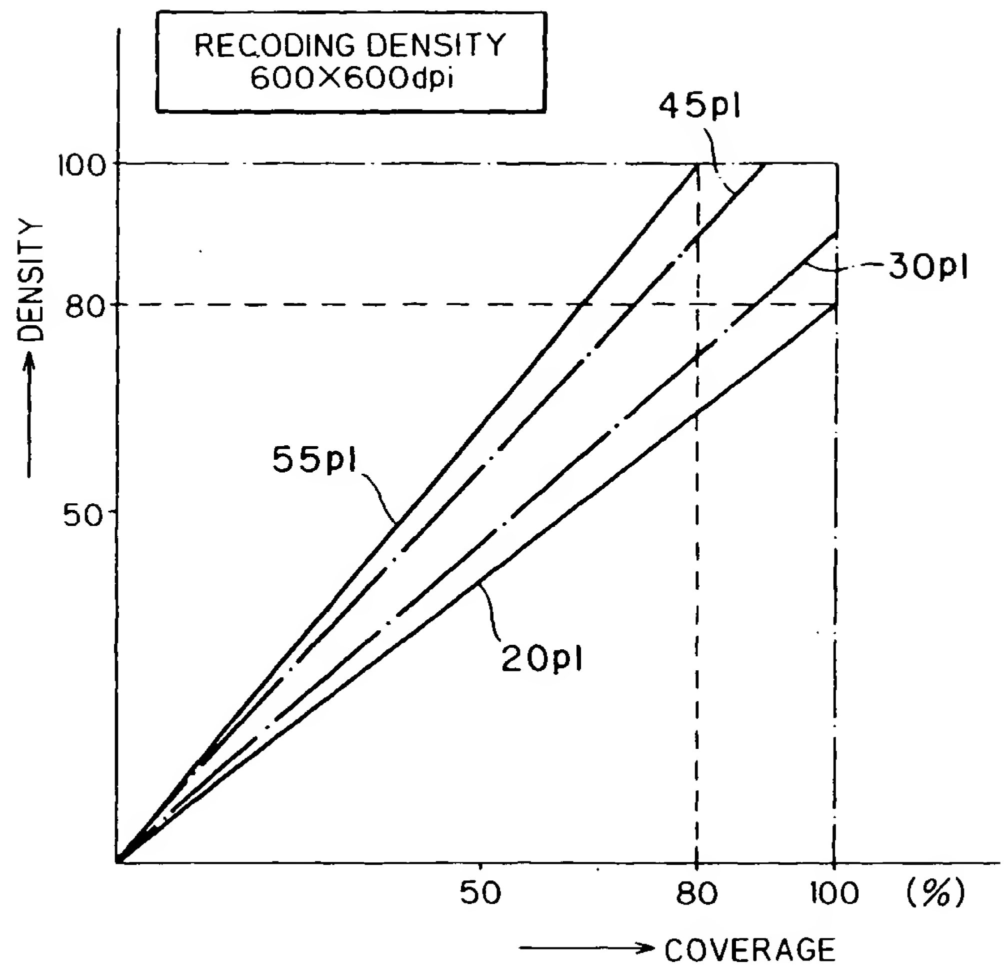

RECODING DENSITY
600X600dpi
45pl
30pl
55pl
20pl
100
80
50
DENSITY
50
80
100
(%)
COVERAGE

FIG. 4(b)

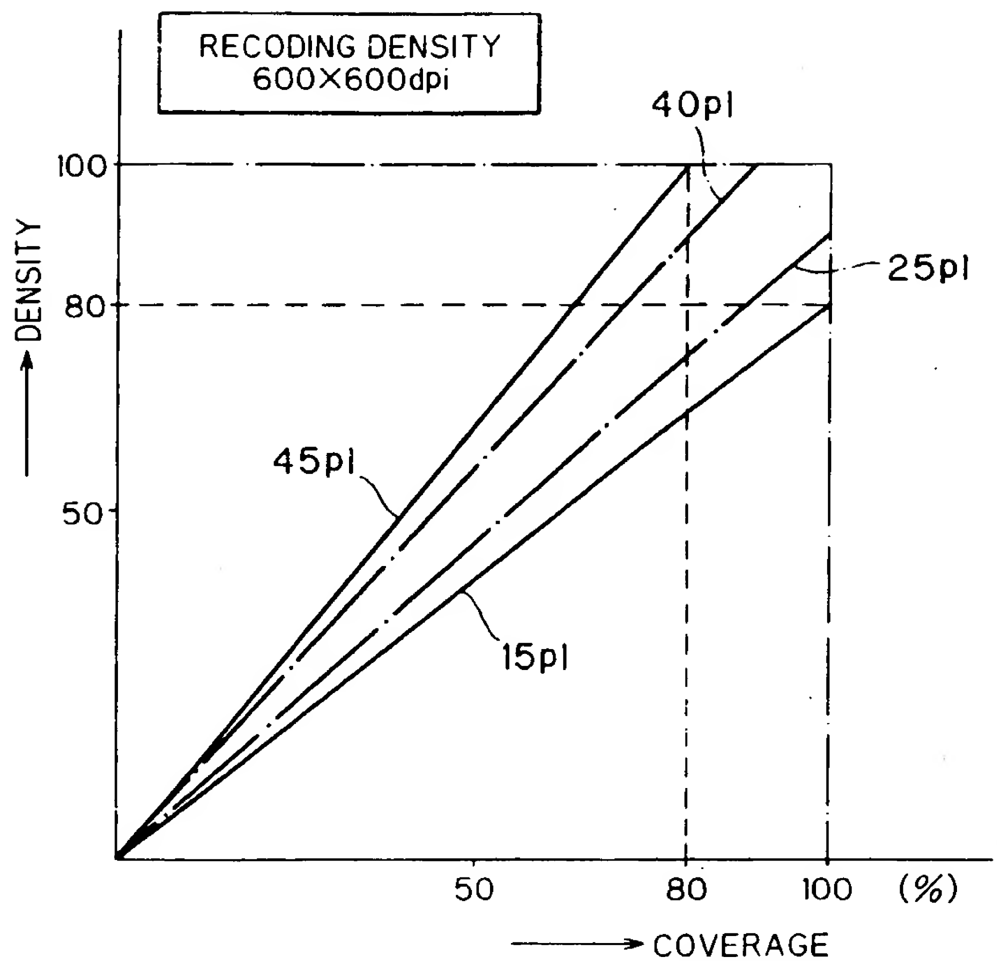
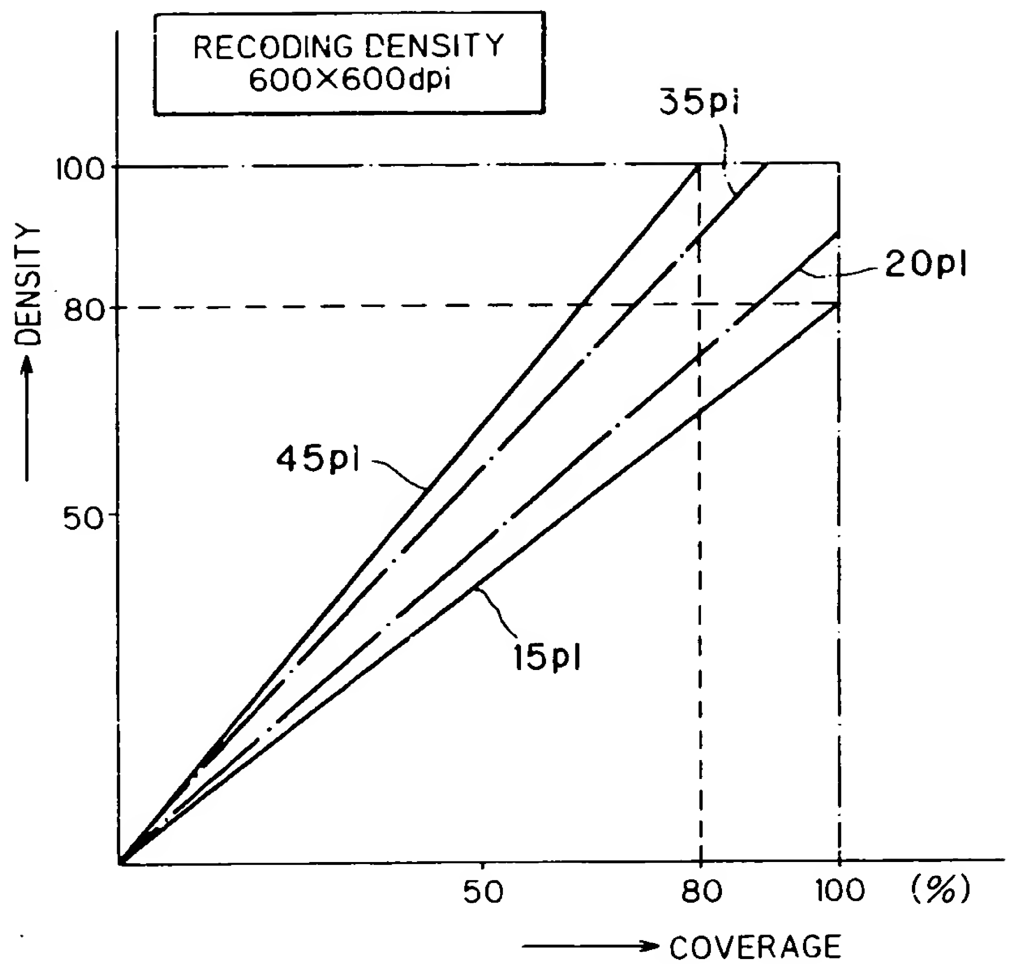

RECODING DENSITY
600X600dpi
40pl
25pl
45pl
15pl
100
80
50
DENSITY
50
80
100
(%)
COVERAGE

FIG. 4(c)


RECODING DENSITY
600X600dpi
35pl
100
80
50
DENSITY
20pl
45pl
15pl
50
80
100
(%)
COVERAGE

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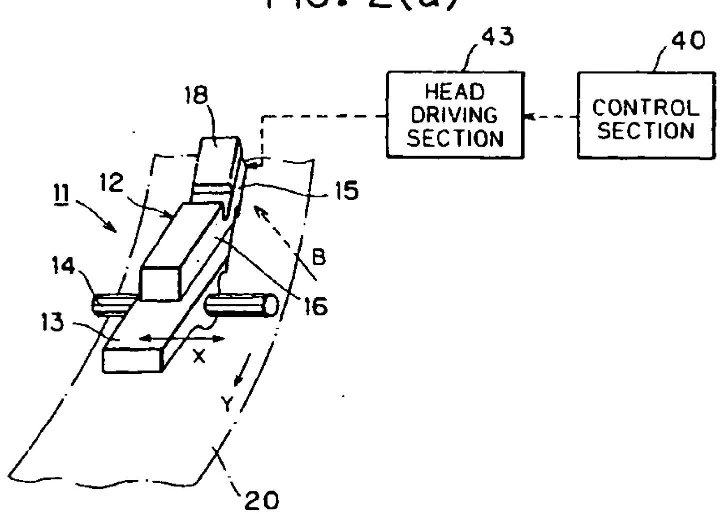
(54) Hot melt ink jet printer ejecting ink droplet of optimum quantity

(57) When a recording density is set to more than 600 by 600 dpi in a hot melt printer, a recording image with excellent quality is obtained when a recording condition is determined to a specific range. For example, a quantity of an ink droplet ejected by the ink jet head is determined so that an ink clinging amount on a unit area of the recording paper is in a range from 7.2×10^6 to 2.1×10^7 pl/inch^2 when the dots are printed in an overall area of the unit area. This range varies when a pair of pressure rollers are provided for applying a pressure to the recording paper on which the dots are printed. This range also varies when a plate-shaped heating element is provided for heating the printed surface of the recording paper.

FIG. 2(a)



EP 0 778 149 A3

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 89 12215 A (SPECTRA INC) * page 11, line 18 - page 12, line 23; figure 2 *	11-13	B41J2/21 B41J11/00
A	* page 8, line 5 * * page 18, line 23 - line 25; figure 9 *	1	
X	US 5 021 805 A (IMAIZUMI MAMORU ET AL) * column 2, line 55 - line 65; figure 2 * * column 3, line 53 *	11-13	
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 424 (M-761), 10 November 1988 & JP 63 159081 A (CANON INC), 1 July 1988, * abstract *	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 April 1998	De Groot, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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